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NANO FOR STUDENTS

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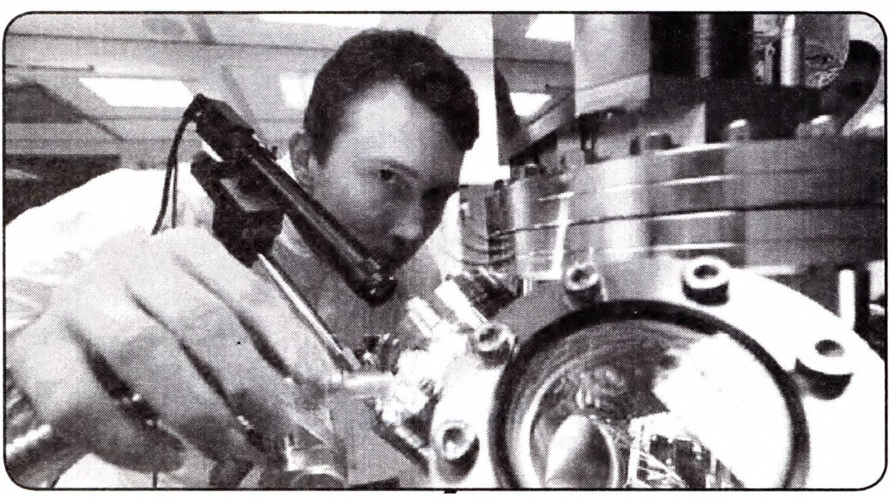


PREFACE

This textbook is intended to teach students mastering English at the two-year courses of "Translators of Technical and Business English". It consists of a number of texts dealing with engineering, quantum mechanics and other fields the learners deal with while getting their basic education.

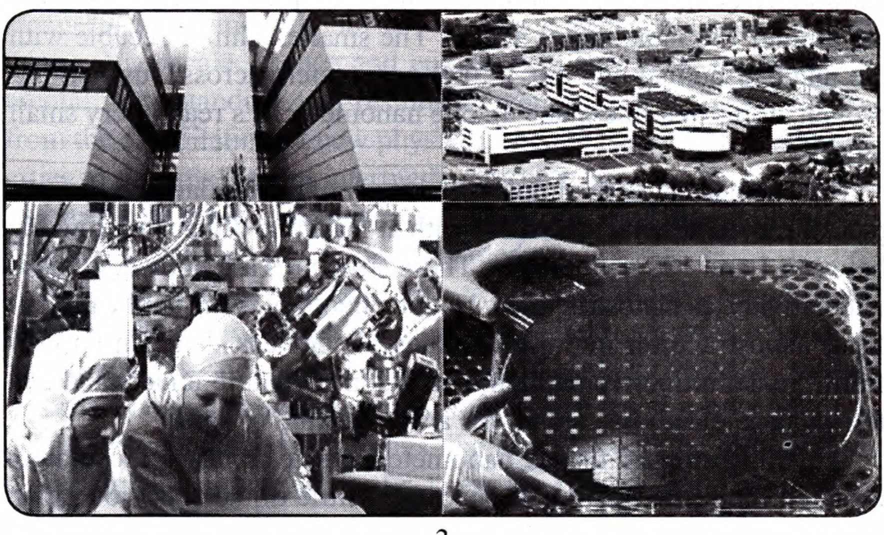
The aim of this textbook is to acquaint the students with the common idea of nanoscience and nanotechnology, i.e. the fabrication and understanding of the matter at the ultimate scale – the molecular one.

This material is intended to help the learners to understand the topical areas in which nanoscience and nanotechnology are concentrated: smart materials, sensors, biological structures, electronics and optics.

Text are intended for class and out-of-class reading, translating and communication.

Notes will help to cope with difficult words and phrases; lexical and grammatical exercises will be useful for students of technical fields of various trends.

Speech exercises will help to form and develop communication skills both orally and in written form and enrich their knowledge in this area.



WHAT IS NANO?

Warming-up:

1. Before you read the text below try to answer the question: " What is NANO?"

2. Now read the text and find the definitions to:

- *nanoscience*
- *nanotechnology*
- *nanometer*
- *nanostructure*
- *nanoscale*

When Neil Armstrong stepped onto the moon, he called it a small step for man and a giant leap for mankind. Nano may represent another giant leap for mankind, but with a step so small that it makes Neil Armstrong look the size of a solar system.

The prefix "nano" means one billionth. One nanometer (abbreviated as 1 nm) is 1/1,000,000,000 of a meter, which is close to 1/1,000,000,000 of a yard. To get a sense of the nano scale, a human hair measures 50,000 nanometers across, a bacterial cell measures a few hundred nanometers across, and the smallest features that are commonly etched on a commercial microchip as of February 2002 are around 130 nanometers across. The smallest things seeable with the unaided human eye are 10,000 nanometers across. Just ten hydrogen atoms in a line make up one nanometer. It's really very small indeed.

Nanoscience is, at its simplest, the study of the fundamental principles of molecules and structures with at least one dimension roughly between 1 and 100 nanometers. These structures are known, perhaps uncreatively, as nanostructures. Nanotechnology is the application of these nanostructures into useful nanoscale devices. That isn't a very fulfilling definition. To explain that, it's important to understand that the nanoscale isn't just small, it's a special kind of small.

Anything smaller than a nanometer in size is just a loose atom or small molecule floating in space as a little dilute speck of vapor.

So, nanostructures aren't just smaller than anything we've made before, they are the smallest solid things it is possible to make. Additionally, the nanoscale is unique because it is the size scale where the familiar day-to-day properties of materials like conductivity, hardness, or melting point meet the more exotic properties of the atomic and molecular world such as wave-particle duality and quantum effects. At the nanoscale, the most fundamental properties of materials and machines depend on their size in a way they don't at any other scale. For example, a nanoscale wire or circuit component does not necessarily obey Ohm's law, the equation that is the foundation of modern electronics. Ohm's law relates current, voltage, and resistance, but it depends on the concept of electrons flowing down a wire like water down a river, which they cannot do if a wire is just one atom wide and the electrons need to traverse it one by one. This coupling of size with the most fundamental chemical, electrical, and physical properties of materials is key to all nanoscience. A good and concise definition of nanoscience and nanotechnology that captures the special properties of the nanoscale comes from a National Science Foundation document edited by Mike Roco and issued in 2001:

One nanometer (one billionth of a meter) is a magical point on the dimensional scale. Nanostructures are at the confluence of the smallest of human-made devices and the largest molecules of living things. Nanoscale science and engineering here refer to the fundamental understanding and resulting technological advances arising from the exploitation of new physical, chemical and biological properties of systems that are intermediate in size, between isolated atoms and molecules and bulk materials, where the transitional properties between the two limits can be controlled.

Although both fields deal with very small things, nanotechnology should not be confused with its sister field, which is even more of a mouthful—microelectromechanical systems (MEMS). MEMS scientists and engineers are interested in very small robots with manipulator arms that can do things like flow through the bloodstream, deliver drugs, and repair tissue. These tiny robots could also have a

host of other applications including manufacturing, assembling, and repairing larger systems. MEMS is already used in triggering mechanisms for automobile airbags as well as other applications. But while MEMS does have some crossover with nanotechnology, they are by no means the same. For one thing, MEMS is concerned with structures between 1,000 and 1,000,000 nanometers, much bigger than the nanoscale. Further, nanoscience and nanotechnology are concerned with all properties of structures on the nanoscale, whether they are chemical, physical, quantum, or mechanical. It is more diverse and stretches into dozens of subfields. Nanotech is not nanobots.

In the next few texts, we'll look in more depth at the "magical point on the dimensional scale," offer a quick recap of some of the basic science involved, and then do a grand tour of nanotech's many faces and possibilities.

Notes:

1) a giant leap – гигантский прыжок
2) melting point – точка плавления
3) concise definition – краткое определение
4) which is even more of a mouthful – которая ещё даже более важная
5) by no means the same – нисколько не одинаковы
6) roughly – приблизительно
7) familiar properties – известные свойства

Tasks:

1. Instead of the gaps insert the right form of the verbs in brackets. Use the Present Simple Tense.

a) Nanoscience (to be) is the study of the fundamental principles of molecules and structures with at least one dimension roughly between 1 and 100 nanometers.

doesn't obey

b) A nanoscale circuit component (not to obey) necessarily Ohm's law.

depend

c) The most fundamental properties of materials(to depend) on their size in a way they don't at any other scale.

d) The prefix "nano" (to mean) one billionth. means

e) Ten hydrogen atoms in a line (to make up)one nanometer. make up

f) Ohm's law (to depend) on the concept of electrons flowing down a wire like water down a river. depends

g) Nanoscience and nanotechnology (to deal with) all properties of structures on the nanoscale. deal with

2. Put as many questions (special, tag, alternative, general) to the sentences from the exercise above as you can.

3. Read the following numbers.

1) 1,000,000,000 of a meter

2) 50,000 nanometres

3) February 2002

4) 100 nanometres

Speaking tasks:

1. Find in the text the information about the difference between nanotechnology and microelectromechanical systems and tell your groupmates about it.

2. Retell the text in 6-7 sentences.

SOME NANO CHALLENGES

Nanoscience and nanotechnology require us to imagine, make, measure, use, and design on the nanoscale. Because the nanoscale is so small, almost unimaginably small, it is clearly difficult to do the imagining, the making, the measuring, and the using. So why bother?

From the point of view of fundamental science, understanding the nanoscale is important if we want to understand how matter is constructed and how the properties of materials reflect their components, their atomic composition, their shapes, and their sizes. From the viewpoint of technology and applications, the unique properties

of the nanoscale mean that nano design can produce striking results that can't be produced any other way.

Probably the most important technological advance in the last half of the 20th century was the advent of silicon electronics. The microchip—and its revolutionary applications in computing, communications, consumer electronics, and medicine—were all enabled by the development of silicon technology. In 1950, television was black and white, small and limited, fuzzy and unreliable. There were fewer than ten computers in the entire world, and there were no cellular phones, digital clocks, optical fibers, or Internet. All these advances came about directly because of microchips. The reason that computers constantly get both better and cheaper and that we can afford all the gadgets, toys, and instruments that surround us has been the increasing reliability and decreasing price of silicon electronics.

Gordon Moore, one of the founders of the Intel Corporation, came up with two empirical laws to describe the amazing advances in integrated circuit electronics. Moore's first law (usually referred to simply as Moore's law) says that the amount of space required to install a transistor on a chip shrinks by roughly half every 18 months. This means that the spot that could hold one transistor 15 years ago can hold 1,000 transistors today. The line gives the size of a feature on a chip and shows how it has very rapidly gotten smaller with time.

Moore's first law is the good news. The bad news is Moore's second law, really a corollary to the first, which gloomily predicts that the cost of building a chip manufacturing plant (also called a fabrication line or just fab) doubles with every other chip generation, or roughly every 36 months.

Chip makers are concerned about what will happen as the fabs start churning out chips with nanoscale features. Not only will costs skyrocket beyond even the reach of current chip makers (multibillion-dollar fabs are already the norm), but since properties change with size at the nanoscale, there's no particular reason to believe that the chips will act as expected unless an entirely new design methodology is implemented. Within the next few years (according to most

experts, by 2010), all the basic principles involved in making chips will need to be rethought as we shift from microchips to nanochips. For the first time since Moore stated his laws, chip design may need to undergo a revolution, not an evolution. These issues have caught the attention of big corporations and have them scrambling for their place in the nanochip future. To ignore them would be like making vacuum tubes or vinyl records today.

Aside from nanoscale electronics, one part of which, due to its focus on molecules, is often called molecular electronics, there are several other challenges that nanoscientists hope to face. To maintain the advances in society, economics, medicine, and the quality of life that have been brought to us by the electronics revolution, we need to take up the challenge of nanoscience and nanotechnology. Refining current technologies will continue to move us forward for some time, but there are barriers in the not too distant future, and nanotechnology may provide a way past them. Even for those who believe that the promise is overstated, the potential is too great to ignore.

Notes:

1) makers are concerned – изготовители озабочены

2) there is no particular reason – нет особой причины

3) according to most experts – согласно большинства специалистов

4) there were fewer than – было менее чем

6) within the next few years – в течение последующих нескольких лет

Tasks:

1. Match the English words from the text and their Russian equivalents:

1) Because of – d	a) как…, так и
2) According to – e	b) поскольку
3) From the viewpoint f	c) слишком

4) Both……and a
5) Aside from b
6) Too - c
7) Probably - g
8) Since- h

~~d)~~ из-за
~~e)~~ согласно
~~f)~~ с точки зрения
~~g)~~ вероятно
~~h)~~ помимо

2. Find in the text sentences with these words and translate them.

3. Define the function of the Infinitive in the sentences and translate them into Russian:

1) To ignore them would be like making vacuum tubes or vinyl records today.

2) To maintain the advances in society, economics, medicine, and the quality of life that have been brought to us by the electronics revolution, we need to take up the challenge of nanoscience and nanotechnology.

3) To do this, electrons will flow through circuits and can be made to perform useful work.

4) To do this without nanotechnology is impossible.

5) To get a sense of the nanoscale, a human hair measures 50,000 nanometers.

6) To deal with nanoparticle optics we should cooperate with the scientists from Lausanna.

7) For these molecules to perform useful functions, they must be easy to assemble.

Speaking tasks: Retell the text using the following models: The text under review is entitled ... It is devoted to ... It examines ... The text touches upon ... The purpose of the text is ... The text describes ... According to the text ...

ELECTRONS

Warming-up:

1. Before reading the text try to answer the questions:

1) What is the electron?

2) When was the electron discovered?

3) What charge does the electron have?

4) What else do you know about this particle?

2. Now read the text and see whether you were right or not.

The chemist's notion of physical reality is based on the existence of two particles that are smaller than atoms. These particles are the proton and the electron (a neutron is effectively a combination of the two). While there are sub-subatomic particles (quarks and the like), protons and electrons in some sense represent the simplest particles necessary to describe matter.

The electron was discovered early in the 20th Century. Electrons are very light (2,000 times lighter than the smallest atom, hydrogen) and have a negative charge. Protons, which make up the rest of the mass of hydrogen, have a positive charge. When two electrons come near one another, they interact by the fundamental electrical force law. This force can be expressed by a simple equation that is sometimes called Coulomb's law.

For two charged particles separated by a distance r, the force acting between them is given as

f = QxQ2/r2

Here F is the force acting between the two particles separated by a distance r, and the charges on the particles are, respectively, Q1 and Q2. Notice that if both particles are electrons, then both Q1 and Q2 have the same sign (as well as the same value); therefore, F is a positive number. When a positive force acts on a particle, it pushes it away. Two electrons do not like coming near one another because "like charges repel" just as two north-polarized magnets do not like to approach each other. The opposite is also true. If you have two particles with opposite charges, the force between them will be negative.

They will attract each other, so unlike charges attract. This follows directly from Coulomb's law.

It also follows from Coulomb's law that the force of interaction is small if the particles get very far apart (so that r becomes very big). Therefore, two electrons right near one another will push away from one another until they are separated by such a long distance that the force between them becomes irrelevant, and they relax into solipsistic bliss.

When electrons flow as an electrical current, it can be useful to describe what happens to the spaces they leave behind. These spaces are called "holes"; they aren't really particles, just places where electrons should be and are trying to get to. Holes are considered to have a positive charge; consequently, you can imagine an electric current as a group of electrons trying to get from a place where there is a surplus of electrons (negative charges) like the bottom of a AA battery to a place where there are holes (positive charges) like the top of a AA battery. To do this, electrons will flow through circuits and can be made to perform useful work.

In addition to forming currents, electrons are also responsible for the chemical properties of the atom they belong to.

Notes:

1) in some sense – в некотором смысле
2) in addition to – кроме, в дополнение

Tasks:

1. Translate the sentences with Complex Subject.

a) Holes are considered to have a positive charge.

b) Hydrogen is known to have one electron.

c) All integrated circuits (chips) are said to depend on Ohm's law.

d) Many sorts of spectroscopy are reported to be used in the analysis of nanostructures.

e) Nanowires are believed to have remarkable conductivity properties.

f) Helium is known to be the smallest naturally occurring atom.

g) Many of the basic rules that define the behaviour of nanostructures appear to be the laws of quantum mechanics.

2. Find in the text sentences with Passive Voice and translate them. Example: The electron was discovered early in the 20th century.

3. Define the Tenses of the verbs in the following phrases:

1) notion is based on
2) electron was discovered
3) the force can be expressed
4) the force is given as
5) the force will be negative
6) it follows from
7) spaces are called "holes"
8) electrons are responsible for

Speaking task: Work in pairs. Put three questions to the text and ask your friend. Then answer your friend's questions.

ATOMS AND IONS

Warming-up:

1. Before you read the text try to give your own definition to atoms and ions.

2. Now read the text and answer the question: What is it said in the text about atoms and ions?

V The simplest picture of an atom consists of a dense heavy nucleus with a positive charge surrounded by a group of electrons that orbit the nucleus and that (like all electrons) have negative charges. Since the nucleus and the electrons have opposite charges, electrical forces hold the atom together in much the same way that gravity holds planets around the sun. The nucleus makes up the vast majority of the mass of the atom—it is around 1,999/2,000 of the mass in hydrogen, and an even greater percentage in other atoms.

There are 91 atoms in the natural world, and each of these 91 atoms has a different charge in its nucleus. The positive charge of the nucleus is equal to the number of protons it contains, so the lightest atom (hydrogen) has a nuclear charge of +1, the second lightest (helium) has a nuclear charge of +2, the third largest (lithium) has a nuclear charge of +3, and so forth. The heaviest naturally occurring atom is uranium, which has a nuclear charge of +92. (You might have guessed it was 91, but element number 43, technicium, does not occur naturally, so we skipped it.) You can see all of this on a periodic table.

In uncharged atoms, the number of electrons exactly balances the charge of the nucleus, so there is one electron for every proton. Hydrogen has one electron, helium has two, lithium has three, and uranium has 92. Since all the electrons are packed around the nucleus, generally the atoms with more electrons will be slightly larger than atoms with fewer electrons.

If the number of electrons doesn't match the charge of the nucleus (the number of protons), the atom has a net charge and is called an ion. If there are more electrons than protons then the net charge is negative and the ion is called a negative ion. On the other hand, if there are more protons than electrons, the situation is reversed, and you have a positive ion. Positive ions tend to be a touch smaller than neutral atoms with the same nucleus because there are fewer electrons, which are more closely held by the net positive charge. Negative ions tend to be a bit larger than their uncharged brethren because of their extra electrons. All atoms are roughly 0.1 nanometer in size. Helium is the smallest naturally occurring atom, with a diameter close to 0.1 nanometer, and uranium is the largest with a diameter of close to 0.22 nanometers. Thus, all atoms are roughly the same size (within a factor of 3), and all atoms are smaller than the nanoscale, but reside right at the edge.

These 91 atoms are the fundamental building blocks of all nature that we can see. Think of them as 91 kinds of brick of different colors and sizes from which it is possible to make very elegant walls, tow-

ers, buildings, and playgrounds. This is like the business of combining atoms to form molecules.

Notes:

1) in the same way – таким же способом

2) on the other hand – с другой стороны

3) ions tend to be – ионы склонны (имеют тенденцию быть)

4) atoms are roughly the same size – атомы приблизительно одного размера

5) the vast majority – огромное большинство

Tasks: 1. Fill in the gaps in the table using the right forms of adjectives and adverbs.

Прилагательные и наречия	Сравнительная степень	Превосходная степень
simple	er	
dense	er	
natural	more	
great	more ?	greatest
light	er	
few	er	
heavy	ier	
many	more	
close	er	
small	er	
general	more	
elegant	more	

2. Find in the text sentences with these adverbs and adjectives and their degrees and translate them.

3. Find in the text sentences with the words: some – the same; a number (of) – the number (of)and translate them. Do you remember any other words similar in spelling but different in meaning?

4. Translate the following word combinations with the noun charge:

opposite charge; positive charge; negative charge; different charge; nuclear charge; net charge;

5. Read the following numbers;

1,989 / 2,000; 91 atoms; +1, +92; 0.1 ; 0.22.

Speaking task: Divide the text into parts. Entitle each part. Use your plan to retell the text.

V METALS

Warming-up:

1. Before you read the text tell your group mates everything you know about metals, for example how many metals exist, what properties(physical and chemical) they have, etc.

Most of the 91 naturally occurring atoms like to cluster with others of the same kind. This process can make huge molecule-like structures containing many billions of billions of atoms of the same sort. In most cases, these become hard, shiny, ductile structures called metals. In metals, some of the electrons can leave their individual atoms and flow through the bulk of the metal. These flowing electrons comprise electrical currents; therefore, metals conduct charge. Extension cords, power lines, and television antennas are all examples of devices where electrical charges move through metal structures.

This can be a little hard to imagine. Think of it as a bank where depositors are atoms, dollars are electrons, and the bank building itself is a macroscopic block of material or a huge molecule. You personally have a certain amount of money, which is probably pretty small in the grand scheme of the economy. However, once you deposit your money in a bank, it gets combined with all the money other people have deposited, and the money flows among the depositors and borrowers as needed. In case it gets lent to someone outside, it creates a business relationship with the borrower roughly analogous to

a chemical bond. If you sever your relationship with the bank, you get to take your money with you, and, ignoring interest, you probably have the same amount you had when you arrived. The free flow of cash though this banking system is analogous to electrical current flowing through the bulk of our metal. The opposite case, where you keep your money under your pillow and there is no free flow or exchange, is analogous to electrical insulators or nonconductors. The analogy isn't perfect, but it may help.

Most metals are shiny because when light strikes a metal, the light is scattered by the moving electrons. Some materials are made of all the same atoms, but are not metallic. These materials tend to be made of lighter atoms. Some examples are graphite, coal, diamonds, yellow sulfur, and black or red phosphorus. They are sometimes called insulators because they do not have moving electrons to conduct charge. They are also generally not shiny because there are no free electrons to reflect the light that shines upon them. Even though we won't worry much about shininess, how free the flow of electrons in a material is matters quite a bit for nanotechnology.

Notes:

1) most of the atoms – большинство из атомов
2) of the same kind – одинакового вида
3) a little hard – немного трудно
4) a certain amount of money – определённая сумма денег
5) a chemical bond – химическая связь
6) quite a bit – совсем немного

Tasks:

1. Say whether the underlined words are Participles or Gerunds?

- Understanding the nanoscale is important, if we want to understand how matter is constructed.
- Chip makes are concerned about what will happen as the fabs start churning out chips with nanoscale features.

2. Find in the text more – ***ing forms*** and decide whether they are Participles or Gerunds.

3. Ask questions to the sentences starting with the words in brackets:

1) There are 91 atoms in the natural world. (How many…………..?)

2) These 91 atoms are the fundamental building blocks of all nature. (What…………?)

3) Hard, shiny, ductile structures are called metals. (What structures…………?)

4) In metals, some of the electrons can leave their individual atoms. (Can………?)(Which electrons…………?)

5) These flowing electrons comprise electrical currents. (What…………?)

6) Therefore, metals conduct charge. (Tag-question)

7) Insulators do not have moving electrons to conduct charge. (Tag-question)

4. Find in the text words and word combinations with opposite meaning to: small, easy, insulators, to become soft, many, to break a business relationship, to borrow money

5. Fill in the table. Use the information from the text and your knowledge in physics.

Conductors	Insulators (nonconductors)

Speaking tasks: 1. Agree or disagree using the following phrases: You are wrong. Quite so. You are mistaken. I think so. I don't think so. To my mind. As far as I know.

- In metals, none of the electrons can flow through the bulk of metal.
- Metals don't conduct electrical charge.
- Metals are shiny due to the effect of light scattering by the moving electrons.
- Grafite, coal, sulfur are some examples of conductors.
- Insulators have moving electrons so they can conduct charge.

2. Tell your desk mate what it is said in the text about metals.

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BIOSYSTEMS

Warming-up:

1. Translate the first paragraph of the text using a dictionary. (Time-- 20 minutes).
2. Now read the whole text and try to divide it into sense groups. Compare your results with those of your group mates.

Of the 91 naturally occurring elements, many are found in biology. As human beings, we require some highly unusual trace metals such as zinc, iron, vanadium, manganese, selenium, copper, and all the other goodies on the side of a vitamin jar for specific biological functions. Of the total weight of most plants and animals, however, well over 95 percent is made of four atoms: hydrogen, oxygen, nitrogen, and carbon. These are also the elements that dominate in most synthetic polymers. The reasons are quite straightforward. These atoms can form a wide variety of bond types; therefore, nature can use them to build some very complex nanostructures to accomplish the jobs of life, and scientists can use them to make new materials. For example, the molecules in our own bodies are responsible for respiration, digestion, temperature regulation, protection, and all the other jobs that the body requires. It clearly requires a wide assortment of fairly complex nanostructures to get the jobs done.

Generally, the molecules found in nature are complex and the source of much dismay to beginning organic chemistry students. For these molecules to perform useful functions, they must be easy to assemble and easy to recognize and bind to by other molecules. They must also be made by biological processes and have variable properties. To do this, these molecules are not usually simple repeating polymer structures such as polyethylene or polypropylene; instead, they are more complex irregular polymers.

There are four large classes of biological molecules. The first three are nucleic acids, proteins, and carbohydrates, which are all polymeric structures. The fourth catchall category is composed of particular small molecules that have special tasks to do.

Proteins make up much of the bulk of biology. Our nails and hair are mostly the protein keratin, oxygen is carried in our blood by the protein hemoglobin, and the protein nitrogenase is responsible for taking the nitrogen out of the air (on the nodules of legumes) and turning it into nitrates that permit plant growth. There are thousands of proteins, some of which are very well understood in terms of structure and function and some of which are still quite mysterious. Proteins are the machines of biology, the functional agents that make things happen.

Nucleic acids come in two categories called DNA and RNA. Both are needed to make proteins, but RNA has not yet been of major interest in nanostructures, so we'll only discuss DNA. It consists of a sugar outside containing negative charges due to the presence of phosphorous and oxygen atoms. Inside, there are stacked planar molecules that lie on top of one another like a pile of poker chips. Each of the poker chips consists of two separate planar molecules, held together weakly, by bridges between oxygens or nitrogens and hydrogens. Because each poker chip is held at both its right and left ends, and because the structure is helical (a spiral), DNA has the structure of a double helix or double spiral staircase. It also looks (and to some extent acts) like a spring. When DNA is tightly wound, it is remarkably compact.

DNA is an almost unique molecule because each poker chip (called a base pair) can have one of four compositions (called AT, TA, CG, or GC). For each position on the strand, it is possible to control which base pair is present. That's because the two planar molecules that compose them can only be chosen from a set of four molecules called adenine, thymine, guanine, and cytosine, which are abbreviated A, T, G, and C. A and T will only bond to each other and not to G or C. Also, G and C will only bond to each other and not to A or T. Because of these limitations, the only possible base pairs are AT and GC and their opposites—TA and CG. These are placed on the double helix, in a particular order, and they code for all the functions of biology. The genetic code is simply an arrangement of base pairs in the DNA

double helix, and it is a code that is read in a very sophisticated way by RNA and by proteins, which use the information to make protein-based biological structures that are the basis of life.

The third class of macromolecules found in biology is the polysaccharides, which are just sugars made of very long molecules. They are crucial to the functioning of the cell, and some of them are found in ligaments and in other biological structural materials. However, they are not yet of major use in synthetic nanotechnology.

The fourth class of biological molecules consists of very small molecules. These include water (crucial for the function of almost everything in biology), oxygen as a major energy source, carbon dioxide as the raw material for making plants, and nitric oxide. This last is a very small molecule consisting of a nitrogen and an oxygen linked together, and it plays many roles in biology from acting as "second messenger," a sort of relay messenger for communications within a cell, to causing erectile function.

There are other molecules that are less small but still crucial in biological applications. They include simple sugars and all drug molecules. Drugs generally work by binding either to a protein or to DNA and causing changes in those structures' functions. Sometimes the binding of these small molecules is very specific and very important.

Notes:

1) of the 91 naturally occurring elements – из 91 встречающихся в природе элементов

2) catch – all – ловушка

3) in terms of – с учётом, на основе

4) to some extent – в некоторой степени

5) adenine – аденин

6) thymine – тимин, $CH_3 \cdot C_4H_3O_2N_2$

7) guanine – гуанин, $C_5H_5NO_4$

8) cytosine – цитозин, $C_4H_3ON_2 \cdot NH_2$

Tasks:

1. Give three forms of the irregular verbs from the text:

To make, to be, to understand, to hold, to have, to read, to bind, to do, to build, to find, to get, to take.

2. Tag-questions. Give the correct tag to the sentences:

a) There are four large classes of biological molecules, aren't there ……?

b) DNA consists of a sugar outside and stacked planar molecules inside, isn't it ……………?

c) Proteins are the machines of biology, aren't they ……………?

d) The fourth category of biological molecules is composed of particular small molecules, isn't it ….?

e) Nucleic acids come into two categories called DNA and RNA, isn't it ……….?

f) These molecules repeating polymer structures are not usually simple, are there …….?

g) Polysaccharides are not yet of major use in synthetic nanotechnology, are there ……….?

3. Fill in the table using the information from the text:

Numbers	Classes of biological molecules	Useful functions of biological molecules
1. nucleic acids		
2. proteins		
3. carbohydrates		
4.		

Speaking task: According to the information in the text there are four classes of biological molecules. Tell your group mates about them.

ELECTRICAL CONDUCTION AND OHM'S LAW

Warming-up:

1. Before you read the text try to formulate Ohm's law. Then read the text and check whether you are right or not.

We usually use all our senses to become aware of objects. Light is seen with the eyes, pressure is felt in the ears and hands, and molecules are sensed in taste and smell. All these senses require an interaction between our bodies' sensory organs and external structures such as molecules or energy or physical objects.

The interactions that are important to taste, smell, and vision all require the flow of electrons within the body. Similarly, electrical charge moves through our nervous systems to inform the brain that a toe has been stubbed or a hand has gotten wet. All these signals, then, really rely on charge motion and, therefore, on Coulomb's law between like and unlike charges. Once again, all chemistry (and even biology) really boils downs to electrons. We know that metals contain free electrons that can move charge and reflect light. But even in non-metallic structures such as our nerves or our noses, electronic interactions and Coulombic forces are important. Moving electrons power our society, from light bulbs to batteries to computers.

Just as Coulomb's law is fundamental for describing the forces due to electrical charge, the current comprised of electrons moving through material also has a defining equation. This one is called Ohm's law.

The most common analogy for the flow of electrons is that of a river. Electron flow through a material is called current and is usually abbreviated as and measured in electrons per second or a related unit. Resistance to the flow of current (analogous to rocks in the stream) is abbreviated as R. Voltage is the last of the key properties in Ohm's law and is the hardest to imagine. Voltage is the motive force that pushes the current along as the downward slope of a mountain watercourse pushes water. Voltage is abbreviated as **V**. **V = IR**

Ohm's law, which simply states that voltage is equal to the current times the resistance, is obeyed in all the electrical and electronic circuits you deal with on a day-to-day basis. It isn't hard to see that this applies. If you have more motive force and the same amount of resistance, current should increase. If you keep motive force constant but increase resistance, current should drop. In almost all cases, this is true. Ohm's law works for hairdryers, computers, and utility power lines. All integrated circuits (chips) depend on Ohm's law.

But not everything obeys Ohm's law. Superconductors are materials in which there is effectively no resistance, and Ohm's law fails. There are other situations, including some special nanostructures such as carbon nanotubes, in which Ohm's law also fails. This leads to some interesting applications and challenges that we'll look at when we discuss molecular electronics.

Notes:

1) to become aware of – знать, сознавать
2) once again – ещё раз
3) to obey the law – подчиняться закону
4) in almost all cases – почти во всех случаях

Tasks:

1. Find in the text the sentences in which the verbs are in Passive Voice and translate them.

2. Change the verbs in Active into Passive according to the model:

Model: They see light with our eyes.---- Light is seen with our eyes.

1) We cannot add continuously energy and charge to matter.
2) Metals contain free electrons.
3) We call coal, graphite, diamond, etc. insulators.
4) A molecule can change its charge state.
5) Quantum mechanics replaced some of the ideas of classical mechanics.
6) We will deal with this material in the next chapter.
7) We can change the charge of an ion by adding or subtracting electrons.

3. From the right column choose the phrase to finish the sentence.

1) Free electrons ...	a) depend on Ohm's law.
2) The voltage is ...	b) called current.
3) Metals contain ...	c) move charge and reflect light.
4) All integrated circuits...	d) free electrons.
5) Electron flow through a material is ...	e) in superconducting materials.
6) Ohm's law fails ...	f) equal to the current times the resistance.

4. Give the definitions of the following words: ***current, resistance, voltage.***

Speaking task:

1. Work in pairs. One will speak about the electrical conduction, the other about Ohm's law.
2. Comment on spheres in which Ohm's law works.

WITHOUT TITLE

Warming-up:

1. Read the text and find the best title to it:

1) Isaac Newton's ideas and formulas.
2) Some of the rules of classical physics.
3) Quantum mechanics and quantum ideas.
4) Laws of quantum behavior.

Until the 20th century, the physics of materials was dominated by Isaac Newton's ideas and formulas, which, with contributions over the next two centuries from many other notable scientists, formed the basis of classical mechanics. These laws describe fairly accurately all motion that you can see at a macroscale such as the movement of cars, the effect of gravity, and the trajectory of a punted football. But when physicists study very small structures at the nanoscale and

below, some of the rules described in classical physics for materials fail to work as expected. Atoms don't turn out to behave exactly like tiny solar systems, and electrons show properties of both waves and particles. Because of these discoveries and many others, some of the ideas of classical mechanics were replaced or supplemented by a newer theory called quantum mechanics.

Quantum mechanics encompasses a host of interesting, elegant, and provocative ideas; however, for our current purposes, only a few significant notions are absolutely necessary. First, at these very small scales of length, energy and charge cannot be added continuously to matter but can only be added in small chunks. These chunks are called quanta (the plural of quantum) if they involve energy, and are units of electronic charge if they involve charge. Changing the charge on an ion, for example, can only be done by adding or subtracting electrons. Therefore, the charge of an ion is quantized (incremented) at the charge of one electron. There is no way to add half an electron.

Ordinary experience does not provide many examples of quantum behavior. Electrical current seems to be continuous, and the amount of energy that can be added to a soccer ball with a kick or a billiard ball with the strike of a cue seems to be continuously variable – the harder we push, the faster the ball moves. Despite this, there are some quantized things in common experience. One good example is money. You can't split a penny, but for amounts greater than one cent, you can always (theoretically) find cash to make exact change.

Many of the basic rules that define the behavior of nanostructures are the laws of quantum mechanics in disguise. Examples include issues such as how small a wire can be and still carry electrical charge, or how much energy we have to put into a molecule before it can change its charge state or act as a memory element.

Notes:

1) over the next two centuries – за последующие два века
2) fairly accurately – достаточно точно

3) because of these discoveries – вследствие этих открытий
4) materials fail to work – материалы не работают
5) despite this – несмотря на это
6) in disguise – замаскированные, скрытые

Task:
1. Translate the underlined phrases from the text.
2. Make up your own sentences with the phrases:
- until the 20th century
- some of the rules
- solar system
- because of these discoveries
- the amount of energy
- despite this

Speaking tasks:
1. Give the main idea of the text in 2-3 sentences.
2. Comment on a) classical mechanics; b) quantum mechanics.

OPTICS

Warming-up:
1. Read the text and answer the question:
How can the achivements of nanotechnology be used in optics?

Quantum mechanics can be significant for a number of issues involved in nanotechnology including understanding aspects of optics, how light interacts with matter. For example, the colors of individual dyes are fixed by quantum mechanics. The large molecule called phthalocyanine, which provides the blue color in jeans, can be changed to give greenish or purplish colors by modifying the chemical or geometric structure of the molecule. These modifications change the size of the light quanta that interact with the molecule and there-

fore change its perceived color. Similarly, different fluorescent lights give slightly more greenish or yellowish hues because the molecules or nanostructures that line the tube and emit light are changed. Even starlight has different colors, coming from stars of different temperatures and from different elements burning in the stellar atmosphere.

Light can also interact with matter in other ways. If you touch a black car on a sunny day, you will feel the heat energy that has been transferred to the metal by the light from the sun. Matter can also give off light energy as in fireworks and light bulbs. In all the cases that we are interested in, the total amount of energy involved in a process does not change (the technical term is that energy is conserved). But by manipulating this energy, we can cause very interesting things to happen.

As metallic objects become smaller, the quanta of energy (the sizes of the energy increments) that apply to them become larger. This relationship is similar to the behavior of drums: the tighter the drumhead, the higher the energy and pitch of the sound. It's also true of bells: generally, the smaller the bell, the higher the tone. This relationship between the size of a structure and the energy quanta that interact with it is very important in the control of light by molecules and by nanostructures and is a very significant theme in nanotechnology.

Notes:

1) phthalocyanine - фталоцианин
2) greenish or purplish colours - зеленоватые или пурпурные цвета
3) yellowish hues - желтоватые оттенки

Tasks:

1. Find in the text opposites to the following words and phrases:

the number, misunderstanding, to act, small molecules, common, the relationship is different, insignificant.

2. Find in the text sentences with Participles and translate them.
3. Think of your own examples with Participles.

Speaking tasks:

1. Work in pairs. Put three questions to the text and answer them.

SPECTROSCOPY

Warming-up:

1. Before you read the texts say what you know about ***SPECTROSCOPY, ELECTROCHEMISTRY, ELECTRON MICROSCOPY.***

Spectroscopy refers to shining light of a specific color on a sample and observing the absorption, scattering, or other properties of the material under those conditions. Spectroscopy is a much older, more general technique than scanning probe microscopy and it offers many complementary insights.

Some types of spectroscopy are familiar from the everyday world. X-ray machines, for example, pass very high-energy radiation through an object to be examined and see how the radiation is scattered by the heavy nuclei of things like steel or bone. Collecting the X-ray light that passes through yields an image that many of us have seen in the doctor's office after a slip on the ice or in the bathtub. Magnetic resonance imaging, or MRI, is another type of spectroscopy that may be familiar from its medical applications.

Many sorts of spectroscopy using different energies of light are used in the analysis of nanostructures. The usual difficulty is that all light has a characteristic wavelength and isn't of much use in studying structures smaller than its wavelength. Since visible light has a wavelength of between approximately 400 and 900 nanometers, it is clear that it isn't too much help in looking at an object only a few nanometers in size. Spectroscopy is of great importance for characterizing nanostructures en masse, but most types of spectroscopy do not tell us about structures on the scale of nanometers.

ELECTROCHEMISTRY

Electrochemistry deals with how chemical processes can be changed by the application of electric currents, and how electric currents can be generated from chemical reactions. The most common

electrochemical devices are batteries that produce energy from chemical reactions. The opposite process is seen in electroplating, wherein metals are made to form on surfaces because positively charged metal ions absorb electrons from the current flowing through the surface to be plated and become neutral metals.

Electrochemistry is broadly used in the manufacturing of nanostructures, but it can also be used in their analysis. The nature of the surface atoms in an array can be measured directly using electrochemistry, and advanced electrochemical techniques (including some scanning probe electrochemical techniques) are often used both to construct and investigate nanostructures.

ELECTRON MICROSCOPY

Even before the development of scanning probe techniques, methods that could see individual nanostructures were available. These methods are based on the use of electrons rather than light to examine the structure and behavior of the material. There are different types of electron microscopy, but they are all based on the same general idea. Electrons are accelerated and passed through the sample. As the electrons encounter nuclei and other electrons, they scatter. By collecting electrons that are not scattered, we can construct an image that describes where the particles were that scattered the electrons that didn't make it through. Under favorable conditions, TEM images can have a resolution sufficient to see individual atoms, but samples must often be stained before they can be imaged. Additionally, TEM can only measure physical structure, not forces like those from magnetic or electric fields. Still, electron microscopy has many uses and is broadly used in nanostructure analysis and interpretation.

Notes:
1) familiar - известный
2) directly - прямо, непосредственно
3) the same - тот же самый, одинаковый

Tasks:

1. Try to remember the meanings of: *a) since, b) before, c) still, d) both ... and, e) through, f) after, g) but* .
2. Find in the text sentences with these words
3. Make up your own sentences with these words.

Speaking tasks:

1. Retell one of the texts.

NANOSCALE LITHOGRAPHY

Warming-up:

1. Read the text paying attention to the lexical difficulties used in it:

1) originally – первоначально
2) to refer to – ссылаться на, указывать на
3) actual – фактический, действительный
4) largely – в основном
5) actually – фактически, на самом деле

The word “lithography” originally referred to making objects from stones. A lithograph is an image (usually on paper) that is produced by carving a pattern on the stone, inking the stone, and then pushing the inked stone onto the paper.

Many types of small-scale lithography operate in very much this way. Indeed, the common methods used to make current computer chips normally use optical or X-ray lithography, in which a master mask is made using chemical methods and light passes through that mask to produce the actual chip structures. It works just like a silk screen for a T-shirt.

Nanoscale lithography really can’t use visible light because the wavelength of visible light is at least 400 nanometers, so structures smaller than that are difficult to make directly using it. This is one of the reasons that continuing Moore’s law into the nanoscale will

require entirely new preparation methods.

Despite this, there are several techniques for doing small-scale lithography. One of the most straightforward and elegant is micro-imprint lithography, largely developed by George Whitesides and his research group at Harvard. This method works in the same way as the rubber stamps that are still found in post offices. A pattern is inscribed onto a rubber surface (in this case actually a rubber-like silicon/oxygen polymer), and that rubber surface is then coated with molecular ink. The ink can then be stamped out onto a surface: this is paper in the post office, but it could be a metal, polymer, oxide, or any other surface in small-scale stamps. Small-scale stamping is more complex, but it is very inexpensive and can be used to make numerous copies. Originally, the stamps worked at the larger micron (1000-nanometer) scale, but recent improvements are bringing it to the nanoscale.

Notes:

1) image - изображение, картинка
2) to ink - покрывать типографской краской
3) at least - по крайней мере
4) rubber - резина
5) visible light - видимый свет

Tasks:

1. Translate the text in writing (45 minutes).
2. Answer the questions:

1) What is meant by lithography?
2) What is a lithograph?
3) What information concerning nanoscale lithography can youfind in the text?
4) What is it said in the text about small-scale lithography?

Speaking tasks:

1. Comment on lithography and its types.

NANOSCALE CRYSTAL GROWTH

Warming-up:

1. Read the text and answer the question:

What have you learned from the text about nanoscale crystal growth.

Crystal growth is another sort of self-assembly. Crystals like salt that are made of ions are called, unsurprisingly, ionic crystals. Those made of atoms are called atomic crystals, and those made of molecules are called molecular crystals. So salt (sodium chloride) is an ionic crystal, and sugar (sucrose, C12H22On) is a molecular crystal.

Crystal growth is partly art, partly science. Crystals can be grown from solution using seed crystals, which involves putting a small crystal into the presence of more of its component materials (usually in solution) and allowing those components to mimic the pattern of the small crystal, or seed. Silicon boules, the blocks used for making microchips, are made or "drawn" in this way.

By making clever choices of seed crystals and growing conditions, it is possible to cause the crystals to assume unusual shapes. Charles Lieber and his group at Harvard University have used nanoscale crystals to seed long, wire-like single crystals of carbon nanotubes as well as compounds such as indium phosphide or gallium arsenide, and of atomic crystals such as silicon. These nanowires have remarkable conductivity properties, as well as many uses both in optics and in electronics.

Notes:

1) partly - частично
2) to mimic - принимать защитную окраску
3) seed - затравочный кристалл
4) phosphide - фосфид, соединение металла с фосфором
5) arsenide - арсенид, соединение мышьяка с металлом
6) remarkable properties - удивительные свойства

Tasks:

1. Try to remember the meanings of the following words: it, one (ones), that (those).

2. Translate the sentences with these words:

1) Crystals like salt that are made of ions are called ionic crystals. Those made of atoms are called atomic crystals, and those made of molecules are called molecular crystals.

2) Polymerization is a very commonly used scheme for making nanoscale materials and even much larger ones – epoxy adhesive.

3) A monomer is one unit, an oligomer is several units, and a polymer is many units.

4) One can understand that the issues of nanoscience and nanotechnology are not easy.

5) When two electrons come near one another they interact by the fundamental electronical force law.

6) We will discuss DNA only. It has the structure of double spiral staircase.

7) It should be noted that all our sences require an interaction between our body's sensory organs and external structures.

3. Give your definitions to: a) a crystal b) an atomic crystal c) a molecular crystal

4. Translate the following word combinations:

1) crystal growth
2) ionic crystals
3) atomic crystals
4) seed crystals
5) component materials
6) nanoscale crystals
7) wire-like single crystals
8) conductivity properties

POLYMERIZATION

Warming-up:

1. Before you read the text try to answer the question: What is polymerization?

2. Read the text and find the Russian equivalents to the underlined words.

As it is known polymers are very large molecules.They can be upward of millions of atoms in size, made by repetitive formation of the bond from one small molecular unit (monomer) to the next. Polymerization is a very commonly used scheme for making nanoscale materials and even much larger ones – epoxy adhesive: work by making extended polymers upon mixing the two components of the epoxy.

Ordinarily, industrial polymers like polystyrene or polyethylene or polyvinylchloride (PVC) are made by building extremely long molecules, with numerous steps that occur sequentially. Controlled polymerization, in which one monomer at a time is added to the next is very important for specific elegant structures. Robert Letsinger and his students at Northwestern University have developed a series o methods for preparing specific short DNA fragments. These an called oligonucleotides from the Greek work "oligo," which means a few. (A monomer is one unit, an oligomer is several units, and a polymer is many units.) The so-called gene machines use elegant reaction chemistry to construct specific DNA sequences.

Building specific DNA sequences is crucial for many reasons. In modern biotechnology, these specific sequences are used to build new biological structures (drugs, materials, proteins), based on the ability of bacteria to reproduce themselves. A synthetic DNA template is introduced into the bacterial DNA, and the bacteria then produce many copies of that particular target protein. The modification of the bacteria's DNA is done using a series of chemical reactions, and the gene machines are used to prepare the specific short oligonucleotides to modify bacterial DNA, capturing that process to produce the protein

of choice. This allows you to effectively make protein factories for nearly any protein you choose. One good example of how this could be used is to make the protein insulin for the treatment of diabetes.

The combination of specific short DNA sequences and self assembly is used extensively to make materials in which a single DNA strand binds to another single DNA strand. This process is called hybridization. Recall that the DNA base A always pairs with T, and the DNA base G always pairs with C. This kind of self-assembly is present in nature – it's how DNA replicates so that cells can multiply. Many synthetic applications of this complementary molecular recognition are used in nanoscience.

Notes:

1) bond – связь
2) ordinarily – обычно
3) sequentially – последовательно
4) polystyrene – полистирол
5) polyethylene – полиэтилен
6) polyvinyl chloride (PVC) – поливинилхлорид
7) oligonucleotides – олигонуклеотиды
8) to replicate – копировать

Tasks:

1. Give the definitions to: oligonucleotides; hybridization; polymerization.

Speaking tasks:

1. Ask each other questions to the text.
2. Retell the text using the phrases: The text under review is entitled ... It is devoted to ... It examines ... The text touches upon ... The purpose of the text is ... The text describes ... According to the text ...

NANOBRICKS AND BUILDING BLOCKS

Warming-up:

1. Before you read the text try to answer the question: What is Richard Smalley famous for?

2. Read the text and name the Russian equivalents to the following English words and word combinations: Nanostructures must be assembled; naturally occurring elements; atomic scale nanostructures; the number of atoms; sulfur group; gold surface; adherent, adhesive and regular films; to form the monolayer; semimolecular building blocks; clever solution chemistry methods.

Nanostructures must be assembled from components. The fundamental building blocks are atoms of the 91 naturally occurring elements. Usually, though, it is inefficient to start with individual atoms. We saw both the strength and the slowness of this approach when we discussed building atomic scale nanostructures using scanning probe microscopy, especially if we are trying to make a macroscopic amount of a material rather than build a single nanoscale machine. Richard Smalley, who won the Nobel Prize for his nanoscience work in 1996, estimated that it could take nanomachines as much as 19 million years to build a few ounces of material building atom by atom because the number of atoms in such a sample is about 6-with-23-zeros-after-it. If one atom were the size of a teaspoon full of water, this many atoms would be about the size of the Pacific Ocean.

Building an ocean one teaspoon at time would be a very slow process and so is building bulk materials atom by atom. Assembling at the rate of a million atoms per second would still take 6-with-17-zeros-after-it seconds to construct a handful of useful material. (For comparison, the national debt of the United States is currently approximately 6-with-12-zeros-after-it dollars.) This is a bit of a damper for those who imagine nanoscale robots (sometimes called "assemblers") running around making everything from cars to clocks, but there are already promising alternatives for making bulk materials based on nanostructures.

Usually, nanostructures are built starting with larger building blocks or molecules as components. You might think of these as nano Legos. Sometimes these are traditional small molecules. The weak interaction of the sulfur group with the gold surface is often used to construct beautifully adherent, adhesive, and regular films of sulfur-ended long molecules on the gold surface. These molecules are called alkane thiols. "Alkane" means a long chain of carbon-carbon bonds of exactly the same sort seen in polyethylene. The "thiol" refers to the sulfur on the end that links (self-assembles) onto the gold surface to form the monolayer. The monolayer can be nanometers thick and very large in the other two dimensions. It is built not from the individual atoms but from the alkane thiol molecules on the gold surface. The National Nanotechnology Initiative was written on gold with alkane thiol ink using dip pen nanolithography.

In addition to individual molecules of the sort that would be found in traditional chemistry laboratories, some very new semimolecular building blocks are used to assemble nanostructures. Two of these nanostructures are so-called carbon nanotubes (first prepared by Sumio Iijima in Tokyo) and nanorods that can be made out of silicon, other semiconductors, metals, or even insulators. These nanorods are made using clever solution chemistry methods, but they can then self-assemble into larger nanoscale structures.

Notes:

1) to assemble - собирать
2) as much as - до, вплоть до
3) sample - образец
4) adherent - прилипший, приставший; присоединенный
5) adhesive - клейкий, связующий, связывающий
6) monolayer - мономолекулярный слой

Tasks:

1. Name the lexical difficulties you have found in the text.
2. Fill in the gaps with the words from the list: blocks, nanorods, self-assemble, nanostructures, nanotubes, interaction, molecules, elements, nanometers.

- .... must be assembled from components.
- The fundamental building blocks are atoms of the 91 naturally occurring ....
- Nanostructures are built starting with larger building blocks or ....
- These nanorods can .... into larger nanoscale structures.
- The weak .... of the sulfur group with the gold surface is often used to construct regular films of sulfur-ended long molecules on the gold surface.
- The monolayer can be .... thick and very large in the other two dimensions.
- Some very new semimolecular building .... are used to assemble nanostructures.
- Two of these nanostructures the so-called carbon .... and .... can be made out of silicon.

Speaking tasks:

1. Sum up the information from the text and give the main idea of the text in 2-3 sentences.

SMART MATERIALS

Warming-up:

1. Try to answer the question: What do you know about Michael Wasielewski and his research?
2. Try to explain the title of the text.

Michael Wasielewski is Chair of the Chemistry Department at Northwestern. One of Wasielewski's major research interests is a complex set of polymeric materials generally referred to as photorefractive polymers. These highly unusual structures contain mobile electronic charges, almost like metals. The mobile charges can be moved to new positions either by shining light on the polymers or by putting them in an electric field. The position of these charged particles is then a sort

of code, a code that can be read by shining different colors of light on the coded polymer, making it work much like a nanoscopic version of a supermarket barcode reader. Photorefractive polymers are of major interest as information storage devices whose storage density can far exceed even the best available magnetic storage structures.

Photorefractive polymers are a particularly complicated and a wonderful form of nanoscale smart materials. In nanoscience, the term "smart material" refers to any material engineered at the nanoscale to perform a specific task. Sometimes smart materials are also dynamic, which means that the material can change its most basic properties or structure based on an outside cue. A simple example of a dynamic smart material is self-tinting automotive glass that is clear most of the time but darkens under intense light to prevent blinding a driver. In the case of photorefractive polymers, the ability to move charges using light or an electric field is engineered into the material at its most basic level. No materials could be made to do this without nanotechnology and manipulation at the nanoscale.

Notes:

1) a complex set of – сложное строение
2) almost like metals – почти как металлы
3) to exceed – превосходить
4) an outside cue – внешний сигнал
5) either ... or - или ... или, либо ... либо
6) dendity - плотность
7) to darken - темнеть, затемнять

Tasks:

1. Look through the text and translate the sentences with the underlined words.

2. Translate the following word combinations: polymeric materials, photorefractive polymers, coded polymer, information storage devices, specific task, storage density smart materials.

SENSORS

Warming-up:

1. Before reading the text answer the questions: What are sensors? Why do we need them? Where are they used and what for?

2. Read the text and finish the sentences using the information from the text.

1) Sensors are structures that will respond ....

2) Sensors can detect sound, light, ...

3) Molecular metal squares are designed to ....

4) When the molecular square recognizes and captures the analyte molecule, ...

5) The sensor will change its colour in the presence of ....

6) These sensors are sensitive enough to detect ....

7) The concept of sensors dates back to the begining of the 19th century, when ....

8) Sensor technology is critical ....

Joe Hupp teaches chemistry at Northwestern University and, in his short scientific career, has worked in many different areas of chemistry and materials. He is athletic, quiet, intense, brilliant, and youthful. One of Joe's major areas of interest has been the development of sensor materials, especially those designed at the nanoscale. Sensors are structures that will respond in a recognizable way to the presence of something we wish to detect. There are sensors for temperature, water, light, sound, electricity, particular molecules, and specific biological targets such as bacteria, toxins, explosives, or DNA.

One way in which Hupp is trying to develop sensors is by using the properties of molecular recognition. He has made some rather complex and elegant molecules that he calls molecular metal squares. These squares are designed to recognize particular target molecules also called analytes ("analyte" literally means that which we wish to analyze). By designing the molecular squares with particular geometries and patterns of molecular electron density, Hupp and his

group have been able to perform a Cinderella-like act—the analyte foot fits into the molecular square shoe and other molecules with different sizes and shapes do not. Once the molecular square recognizes and captures the analyte molecule, we must be able to recognize that the capture has in fact taken place, which is usually done by shining light onto the square. The combination of square plus analyte absorbs energy from the light in a different color range (frequency or wavelength) than the square without the analyte or the analyte alone. This means that if you monitor the sensor, it will change color in the presence of the analyte. These sensors are sensitive enough to detect fewer than 10 molecules of an analyte, so for high-precision tests you might not see the change with the naked eye, but it isn't hard to construct lab equipment that can see it. This allows the squares to be among the most sensitive sensors ever made.

Sensor technology is critical to the control and monitoring of the environment. The concept of sensors is not new—Humphrey Davy developed a miner's lamp that sensed the presence of gas in coal mines at the beginning of the 19th Century—but nanotechnology will make whole new classes of ultrasensitive sensors possible.

Notes:

1) rather complex – слишком сложный
2) in fact – на самом деле, фактически
3) analyte – аналит, определяемое при анализе вещество
4) high-precision tests – тесты высокой точности
5) with the naked eye – невооружённым глазом

Tasks:

1. Reread the text, divide the text into logical parts and entitle them.
2. Write a summary (3-5) sentences.

Speaking tasks:

1. Retell the text in your own words.

NANOSCALE BIOSTRUCTURES

Warming-up:

1. Try to answer these questions before you read the text. Then read the text and see whether your answers are right.

- What is Stupp's research devoted to?
- What is his major research?
- What is meant by nanoscale biostructure?

Sam Stupp teaches chemistry, materials science, and medicine at Northwestern University. He heads an institute at Northwestern devoted to human repair, which means that one of his major research aims is the utilization of self-assembly and nanostructures to repair, rather than to remove or replace, parts of human bodies when they run into trouble. A major focus of his research, and a major focus of nanoscience generally, is so-called nanoscale biostructures. These structures, designed at the nanoscale, can mimic or affect a biological process or interact with a biological entity.

One example of a nanoscale biostructure is provided by a self-assembling "artificial bone," very recently developed in Stupp's group. The molecules that make up the bone are held together by chemical bonds. These molecules, in turn, have interactions among them that are weaker than true bonds (more like those that create surface tension in water), but that hold the molecules together with each other in a particular shape, in this case a cylinder. The molecules in the bone are designed to occupy space in a particular way so that they will assemble spontaneously to form the desired shape, and, once assembled, so that they will be packed densely enough for the bone to be very strong. The structure of packed molecules can be made compatible with the human immune system by properly choosing the head groups of the molecule, the groups of atoms that ultimately form the outer shell of the artificial bone template. The outer shell is also designed so that natural bone begins to form around it like coral on a reef or gold on a piece of plated jewelry. This is key to human

repair—allowing the body to fix broken or damaged tissue naturally rather than replacing it with a steel or ceramic implant.

Because the biological realm is full of nanostructures, biomedical applications and biomedical investigations constitute a major part of the nanoscience landscape.

Notes:

1) rather than – а не, скорее чем
2) to run into trouble – попасть в беду
3) in turn – в свою очередь

Tasks:

1. Translate the following word combinations from the text: materials science, human repair, research aims, nanoscale biostructures, biological entity, chemical bonds, human immune system, head groups, outer shell, nanoscience landscape.
2. Make up your own sentences with the underlined expressions from the text.

Speaking tasks:

1. Retell the text using the phrases: The text under review is entitled ... It is devoted to ... It examines ... The text touches upon ... The purpose of the text is ... The text describes ... According to the text ... One should add … One may stress… I would add that … In conclusion …

ENERGY CAPTURE, TRANSFORMATION, AND STORAGE

Warming-up:

1. Before you read the text below try to answer the question: How is energy generated, transformed and stored today?
2. Read the text and say about Graetzel's first major contribution.

Michael Graetzel is a chemist at the University of Lausanne in Switzerland. He has curly hair, a shy and engaging smile, and a tremendous enthusiasm for what he does. Graetzel has devoted much of his career to the invention, study, and development of nanostructures for dealing with issues of energy—its capture, transformation, storage, and distribution. Because industrialized societies require massive amounts of energy, both in continuous supply to homes and businesses and in portable energy for gadgets and personal electronics, the area of energy management comprises one of the major domains of nanoscience.

Graetzel's first major contribution came in the development of something now called the Graetzel cell. In a Graetzel cell, a dye molecule is used to capture the energy from sunlight. The molecule absorbs the light, going into a higher energy state. In this high energy state, the molecule actually separates charge by passing an electron from the dye molecule to a nanoparticle of a white crystal called titanium dioxide, which may be familiar as the pigment material in white house paint. The separated charges (positive charge remaining on the dye molecule, negative charge shifted to the titanium dioxide nanoparticle) are then allowed to recombine using a set of electrochemical reactions. In this recombination, some of the energy that was originally captured from the sun by the molecule is released as electrical current passing through an external circuit. Originally, Graetzel cells were used to illuminate bathroom scales and Swiss watches, but they also exemplify a major worldwide effort for capturing sunlight to provide energy sources that are efficient, nonpolluting, safe, and inexpensive. Graetzel cells currently have efficiencies exceeding 7 percent and can be produced using silk screening techniques, which makes them cheaper to make than most traditional photovoltaic cells.

Nanoparticle optics deals the capture, control, emission, transmission, and manipulation of light. Because light is one of the most important sources of energy, this area of nanoscience and technology is crucial for dealing with the world's energy demands.

Notes:

1) curly hair - курчавые волосы

2) gadgets - технические новинки

3) dye - краситель

4) to capture - улавливать, захватывать

5) to store - хранить

Tasks:

1. Use the information from the text and complete the sentences.

1) Because modern societies require a lot of energy	a) exceeds seven percent.
2) Now Graetzel cells can be	b) used to take the energy from sunlight.
3) At first cells were used	c) nonpolluting and inexpensive energy sources/
4) One of the major Graetzel's contributions is	d) to illuminate watches and scales.
4) Today the efficiency of Graetzel cells	e) produced using silk screening techniques.
5) Graetzel cells also provide	f) the area of energy management is one of major of nanoscience.
6) In cell, a dye molecule is	g) called the Graetzel cell.

2. Reread the text, divide it into logical parts and entitle them.

3. Give the definition of the Graetzel cell.

Speaking tasks:

1. Answer the following questions:

1) What has M. Graetzel devoted his career to?

2) Why does the area of management comprise one of the major domains of nanoscience?

3) How does the dye molecule capture the energy from sunlight?

4) What are the fields of Graetzel cell application?

SUPPLEMENTARY READING

Tasks:

1) Divide the text into logical parts.

2) Entitle each part and make up a plan of the text.

3) Retell the text according to the plan.

4) Comment on…

5) Find the predicate(s) and define the Tense(s).

6) Using the text explain the expression(s)…..

7) Explain the following terms….

8) Work in pairs. Put questions to the text and answer them.

9) Express your agreement and disagreement. Use the following phrases:

You are right. You are wrong. Quite so. You are mistaken.

I think (don't think) so.

As far as I know…. I agree (disagree) with you.

According to the data....

10) Name the facts of the text which refer to….

11) Name the paragraph which contains the information about….

12) Find in the text and name the most important, in your opinion, information.

13) Name the new facts(information) which you have found in the text.

14) Reread the text and find the info about….

15) Compare two texts and find their similarities(differences)

16) Write an abstract according to the scheme:

T*he text under review is entitled.... It is devoted to the problem of... It examines... The text touches upon ... The text describes...*

According to the text... Special attention is given to...

It is mentioned...

As far as...is concerned... In conclusion it is said...

OPTICS

Ching Tang is a chemist at the Eastman Kodak Company in Rochester. Kodak's name has long been synonymous with one kind of optics, the kind that allows us to capture memories on film. Tang is soft spoken and charming, but his unassuming manner masks the tremendous creativity that he has shown throughout his scientific career. In 1987, Tang's group at Kodak was the first to demonstrate that organic molecules could be used to make light directly and efficiently from electricity. The area that Tang invented in that year has become known as organic light-emitting diodes (LEDs), and all signs are that it will be a major technology for illumination in areas from automobile dashboards to room lighting to computer screens.

Tang's original work was based on molecular considerations, rather than any nanoscale structures. More recent work throughout the world has demonstrated quite clearly that taking these LED structures down to the nanoscale produces major gains in efficiency, control, cost, and lifetime.

Using electricity to produce light, as is done in these LEDs, is essentially the inverse process of natural photosynthesis or of the Graetzel cell discussed earlier in this chapter. Electricity is used to produce light in the light-emitting structures, while light is captured to produce electricity in the photocells. Both are major areas of study in the development of nanoscience.

ELECTRONICS

Electronics is currently *"the workhorse technology"* for computing and communications as well as a major component of consumer goods. Though few of us are old enough to remember crystal radios, some can remember vacuum tube electronics. When we first talked about the advent of the transistor and then of integrated circuit and silicon chip manufacture, we asserted that these were powerful economic, societal, and technological forces and that their development

led to the growth of high-tech applications, which has dominated the industrial and commercial progress in the developed world in the last third of the 20th century. The ongoing development of electronics continues to provide a huge bounty both financially and in terms of quality of life. We also said that we are unlikely to continue at anything like our current rate of progress in electronics development unless there is a major technological revolution in the way electronics work and are made. That revolution may be made possible by nanotechnology.

To maintain focus, we will limit our discussion of electronics largely to chip-based structures since the current technologies surrounding them are those most rapidly reaching their limits. We will also say something about memory and interconnect structures that are needed for efficient computation. In making this choice, we intentionally will ignore the tremendous applicability of nanoscale electronics in many communications and consumer marketplaces, as well as in other areas ranging from radar to radios to routers. In keeping with the theme under investigation we will focus on some of the most challenging and promising areas. There, as we've already stressed, nanoscience and nanotechnology will pervade all aspects of our lives for the next several decades.

At first sight, the Moore's law graph seems absolutely smooth, suggesting that advances in electronics development have been continuous. Actually, they have been episodic. A large number of improvements have been developed by creative engineers, allowing chip-based technology to become cheaper, denser, and more efficient. Still, several fundamental issues suggest that there is a brick wall ahead that will block this ongoing improvement. This wall will arise from some fundamental physical limits due to the nature of electrical conduction and the requirement that a transistor must be able to be turned on or off by voltage across its gate. When the transistor gets too small, quantum mechanical leaking of the electron through the transistor will mean that it is no longer clear whether the transistor

is supposed to be on or off. This will call for entirely new logic approaches or, perhaps, for different nanoscale structures.

Advanced technology within the semiconductor industry is already at the nanoscale. A 130-nanometer technology is becoming standard in current chips, and advanced prototype models that reduce the size substantially further are available. As we have already indicated, manufacturing such nanosize objects using the top-down lithographic techniques that all semiconductor fabrication facilities now utilize is driving up costs at an exponential rate. Given the increased cost and the remarkable tolerances necessary to continue Moore's law, other schemes for electronics become attractive.

SOFT MOLECULE ELECTRONICS

Using more traditional organic and organo-metallic molecules as electronic components offers some aspects that are more attractive than using nanotubes, including both relative ease of assembly (and potential for self-assembly) and some of the control and recognition (including biorecognition) features that molecules permit. While most organic molecules are soft insulators—think of wax and polystyrene, tar and fingernails—under particular conditions these molecules can conduct current. Indeed, current transport in molecules can be controlled either by chemistry or by electromagnetic fields.

The advent of scanning tunneling microscopes has led to burgeoning interest and activity in the field of molecular electronics. Within the past two years, scientists have demonstrated that single molecules can switch like transistors, that molecules exhibit nondissipative passage of electrical current (effectively superconduction, but via a different mechanism—this is something not previously demonstrated in traditional integrated circuits of any size), that molecular structures can be true superconductors, and that molecules can be used as active switches in electronic circuits. This remarkable set of discoveries has placed new emphasis on the possibility of using molecules as

components in electronic devices. These possible applications range from molecular interconnects or wires through molecular switches to molecular insulators, molecular assemblers, and molecular memories. This would lead to the highest-density computers possible using current computer architectures. Efficient assembly of these devices is now perhaps the greatest challenge of molecular electronics.

NANOBUSINESS TODAY

The landscape of nanotechnology is already being split among three kinds of entities. First are the open research labs including universities, national laboratories, and programs within government agencies such as National Institutes of Standards and Technology (NIST) and the National Institutes of Health (NIH). Second are large corporations with research, development, manufacturing, marketing, and distribution capabilities such as Merck, IBM, Dow, Kraft, 3M, and Agilent (formerly part of Hewlett Packard), and third are the start-ups and spin-offs formed by professors, researchers, graduating students, and others who have seen an idea in a laboratory and want to commercialize it.

Nanoscience is a moving target; there are many directions in which research can go. Commercial need for specific products will certainly nudge research to move in certain directions, but there is still so much to be understood about the fundamental behavior of nanostructures that whole new areas of interest could emerge. A large amount of money is needed for basic groundwork that may or may not result in commercial products. Universities and government institutions exist to do this kind of pure scientific research. It is important that governments and corporate donors around the world actively promote this and that institutions create cross-disciplinary centers for nanotechnology. There are already several key centers of this type in the United States. They include Northwestern, Harvard, MIT, Rice,

Illinois, Purdue, Cornell, UCLA, Texas, and Berkeley. Unlike silicon technology, nanotechnology isn't rooted at the coasts.

Many universities are equipped for nanoscience research; however, even for them, it will not be business as usual. Not only will they require specialized centers for nanoscience, but they may also face the "brain drain" that characterized the dot com bubble at places like MIT and Stanford. Top researchers will find themselves with discoveries of great commercial value and will be put in a position of having to choose whether to launch enterprises, license their discoveries, put them in the public domain, or put them in the trust of their institutions. These researchers and their students are already being seen as the technology transfer agents of nanotechnology, and they will be given huge compensation offers if they move to the private sector. This might make it very hard for universities to retain them. Unlike information technology, where almost anyone can train to be a technician and get to the point of being productive in a matter of months, nanoscience research will, in most cases, require in-depth scientific knowledge and a PhD-level background. In the short term, there is likely to be a shortage of talent, especially if nanotechnology start-ups become more common.

Big corporations will have some advantages in the world of nanotechnology. Many of them can already fit nanotechnology into existing product lines, and they will prevail where manufacturing and distribution can be expensive and there are massive economies of scale. Some obvious winners will be companies in the pharmaceuticals and microchip industries. Pharmaceutical companies have the clout to get drugs through the Food and Drug Administration (FDA) approval and the credibility, channels, money, and legal wherewithal to get them to market. Microchip makers have billion-dollar fabrication facilities, things beyond the budget of even the best-funded start-ups.

Start-up companies will fill the remaining part of the nanotechnology landscape. At this time, the very words "start-up company" are sometimes enough to get you quietly blackballed from polite conver-

sation or sent out to play with the other children, but this is unfair. The concept of start-ups remains sound, despite the abuse it has received in the last few years. With the benefit of 20/20 hindsight, many of the mistakes that characterized the "dot bombs" can be avoided.

HIGH TECH, BIO TECH, NANOTECH

There are precedents for predicting how the nanotech market will be divided between large and small. Looking at the way that the high-tech and biotech industries have developed, a trend emerges where smaller start-up companies tend to succeed with revolutionary technology and larger enterprises tend to succeed with evolutionary technology. For example, think of the great success stories of the high-tech market (primarily the information technology, Internet, and personal computer industries). They are primarily relatively new companies like Microsoft, Apple, Dell, Compaq, Yahoo!, eBay, and Cisco more than the old reliables such as IBM, HP, Siemens, Hitachi, and Sony. This is because home PCs and the Internet did not replace or evolve from older computers and older networks, but rather they were entirely new products that replaced nothing.

The biotech industry stands in sharp contrast to this. Although some of the methods of biotechnology, based on molecular biology, nucleic acid and protein chemistry, and molecular manipulation are new, the aim of most of this molecular wizardry has been continued progress in the established business of drug development. For this reason, the channels to market, expertise, and other assets of the grand old names like Merck, Glaxo, Pfizer, Lilly, Abbott, Baxter, and Pharmacia allowed these corporations to continue to dominate the industry. It is true that biotechnology has brought several new big winners such as Genentech and Amgen, but because most of its products were not entirely new, most of its profits wound up in traditional groups.

Because nanotechnology is a method for improving many evolutionary and revolutionary technologies, ranging from something as

straightforward as paint or glass or nonskid surfaces to such futuristic ideas as colorimetric nanosensors and neuro-electronic interfaces, it will have some aspects of both the biotech and the high-tech industries. Still, because many of the applications of nanoscience that are visible lie in the consumer, medical, agricultural, and energy arenas, it is probably true that most of the big hits will be owned by major industrial players who are already present in those markets. This does not mean that investments in start-ups, medium-sized companies, and growth firms centered on nanotechnology will not succeed. They certainly succeeded very well in the biotech business, mostly because these start-ups and young companies developed products, processes, know-how, and intellectual property. They became very attractive takeover candidates and were generally bought by big players. That is to the benefit of all involved. Investors and developers in small companies did very well economically; the products were developed rapidly and efficiently; and the development of the products into actual consumer marketplace items was handled by the strength, channels to market, and sophisticated distribution of the major players.

Shake-out and development patterns within nanotechnology are not yet clear, but it is the bet of the authors of this book that it will look more like biotech than like information technology or high-tech.

NANOTECHNOLOGY: HERE AND NOW

So what will life be like in the heyday of nanotechnology? How will its development actually impact people's day-to-day lives? The advances in creating ultra-fast computers, molecule-sized mechanical parts, and super-strong materials all sound grand, but what do they ultimately mean to me in my life?

These questions are coming from people who see the nanotechnology hype but aren't necessarily technophiles or long-term planners. Mentions of nanotechnology in the press have grown exponentially as nano has become hot, but when will nanotechnology actually enter our lives and become not the next big thing, but the current one?

To some extent, the answer is "now." The original ideas behind nanotechnology go back some 20 years, but the first few nano-inspired inventions are just starting to hit store shelves. Even so, the first generation of nanogoods is still only a hint of what is to come.

Nanotechnology has been making its presence felt in industry for some time, and many applications are already standard. Because of the current national debate regarding energy policy and oil, a perfect example may be petroleum refining. Zeolites, the molecular sieves are now used to extract as much as 40 percent more gasoline from a barrel of crude than the catalysts they replaced. This technique was first developed by Mobil and by some estimates saves approximately 400 million barrels of oil per year (around $12 billion) in the United States alone. Because this approach has been used for many years, don't expect it to drive down your pump prices any time soon, though it did when it was first developed. Even so, zeolites do show how significant (and how understated) the use of nanotechnology can be.

So, what forms of nanotechnology are we most likely to see and touch? Perhaps first on the list of consumer nanogoods are smart materials such as coatings and laminates. Even though you may not put "coatings and laminates" on your grocery list, they are around you every day. In this case, they are thin layers of various materials that are engineered at the nanoscale to enhance other products in various ways. For example, the windows in new Audi A4 series cars are coated with glass laminates that block harmful ultraviolet radiation that can cause skin cancer. Additionally, the Institute for New Materials in Germany is manufacturing windows that contain a nanolayer of material that changes from clear to dark blue when a switch is thrown. This approach could be used as an alternative to window shades or window tinting, and some suppliers are now coating windows and other surfaces with ultra-hard scratch-resistant layers that may make car-keying a thing of the past.

In addition to windows, German and Japanese manufacturers such as Nanogate Technologies have started selling bathroom and kitchen tile that cannot get dirty since it is impossible for dirt and grit parti-

cles to cling to the coating in much the same way that food cannot stick to Teflon pans. These self-cleaning tiles can also be impregnated with biocidal (antimicrobial) nanoparticles. This prevents growth of rots and fungi that infest bathrooms and enhances overall sanitation. These tiles may put an end to the ever-unpleasant task of bathroom cleaning, a prospect many might consider sufficient cause to support all of nanotechnology.

But early support for nanotechnology did not come from bathroom cleaners; it came from groups like computer enthusiasts. This support emerged not just because computer users tend to be fans of new and emerging technology of all kinds, but also because nanotechnology offers so much to the world of computing. Even for those who don't particularly want a quantum computer on their desktops, a variety of very exciting products will soon be available. You won't be able to buy a Pentium-DNA for Christmas this year, but you will be able to start placing orders for some new kinds of computer displays.

Displays have been a focal point of computer engineering for last few years. Slowly, clunky TV-like cathode-ray tubes (CRTs) have been replaced by flat-panel liquid-crystal displays (LCDs). LCDs are more energy efficient, cause less eyestrain, and are more compact that CRTs. But the viewable area of LCDs is typically smaller than that of CRTs (few exceed 24 inches), their images are generally less bright, and they must be viewed directly, not from the side. Also, LCDs tend to refresh the images that they display slowly, which can cause animation and video to look sloppy. Enter light-emitting diode displays.

Everyone has seen LEDs. They are the bright pin lights often used on electronics as power and status indicators or as backlights. Using nanotechnology, these ultra-bright little lights can now be integrated on a panel densely enough to act as a display. By putting them in three-LED clusters (one red, one green, one blue) and mixing them while controlling intensity, any color can be created. Nano-based LED displays are the size of LCD displays but are even brighter than CRTs and allow for smooth, crisp animation. Also, like LCDs and un-

like CRTs, LED displays don't require digital-to-analog conversion of images, a process that reduces picture fidelity. But LED displays have existed for some time; many signs already use them (such as the NASDAQ sign in Times Square, which contains some 19 million individual LEDs). What nanotechnology adds is the ability to make them small enough to put them into color-controllable clusters and pack them densely enough to create an image that is smooth to the human eye.

Nanotech is also taking a stab at improving the venerable CRTs. Using nanotubes to replace scanning electron guns, manufacturers like Samsung are shrinking these screens and reducing power consumption. It is even possible that these screens will be small, light, and efficient enough for use in laptop computers.

Another display technology, which one of its developers (the Irish company Ntera) is calling NanoChromics and another (E Ink) is calling electronic ink, is breathing new life into an idea from the 1990s that wasn't then feasible—digital paper. The idea behind the original digital paper was to create hand-held computers with ultra-sharp screens that could be held and read like a book. You could transfer digital files onto these computers so that you could store as many books and documents as you liked and eventually the world would become paperless. But there were a number of problems with these early displays: they were power-hungry, bulky, and never as easy to look at as a paper image (screen resolutions were still typically four times lower than print resolutions). Nanotechnology changes this: some new digital paper displays use the same chemicals that are used in paper to create a paper-like look, and picture elements, or pixels, are bistable so that once they are programmed to display a certain image they maintain that image without using additional power. Although people may still prefer the touch and feel of a book for many reasons, digital paper is very likely to take a substantial role in signage, since current technology for large format printing, error-correction, and shipping remains expensive.

Nanotechnology is not just present in fields that are traditionally high tech. Nano is now, literally, in fashion. Advances in molecular-scale composite materials have allowed companies like Nano-Tex to create next-generation cloth and clothing. Materials almost totally resistant to stains and materials that combine the comfort of cotton or natural fibers with the strength and durability of synthetics like nylon are already hitting the market in products from Eddie Bauer, Lee Jeans, and Nano-Tex parent, Burlington Industries. In addition to convenience and sharp looks, other nanotechnology-based fabrics incorporate the same sorts of biocidal agents present in the ever-clean bathroom tiles. These fabrics could be of great use in hospitals, where pathogens are common and patients are currently at significant risk from each other's infections.

Another industry in which new technology is frequently applied is sports equipment. Carbon fiber and graphite composites made their debuts in lightweight bikes and America's Cup sailboats. Fiberglass and plastics have been used for better football and hockey pads. And now nanotechnology is taking the field. Wilson's Double Core tennis balls use a nanocomposite clay to keep balls bouncing longer (they last two to four times as long according to Wilson and are now the official balls of the Davis Cup), and Babolat has introduced super-strong nanotubes into its tennis racket line for improved torsion and flex resistance. Nanotubes are sure to see wider adoption in sports equipment as their prices come down (nanotube-enhanced golf clubs are on the way), but for now we'll mostly see them in the hands of the pros while we are in the stands.

A last area where nanotechnology truly shines is medicine. While medicine has not traditionally been considered a consumer market, nanotechnology may be changing that. Home pregnancy tests have already seen improvements in ease of application, speed of results, and overall accuracy since they have started employing nanoparticles, and other home tests are becoming feasible. Some scientists hope to see tests for everything from anthrax to AIDS made simple enough for self-application through the use of nanotechnology, and

goods like braces and prosthetics are already targets of early nanotechnology ventures.

All in all, while much of the promise of nanotechnology remains in the future, it is already slipping into our lives through our houses, our computers, our games, and even our bodies. The age of nanotechnology is truly upon us.

CARBON NANOTUBES

The carbon nanotube structure has already made its appearance several times because it represents an entirely new form of matter. Single-walled nanotubes can be either semiconductors or metallic. Nanotubes are also very stiff and very stable and can be built with their length exceeding thickness thousands of times.

Nanotubes can, however, exhibit even more interesting behavior. Scientists such as Cees Dekker in Delft, Paul McEuen at Cornell, Phaedon Avouris at IBM, and Charles Lieber at Harvard have demonstrated that single nanotubes can actually act as transistors. Pairs of nanotubes, or crossed nanotubes, have been shown to work as logic structures. These experiments constitute a proof of principle that nanotube logic, at an unprecedentedly small scale, can actually provide a modality for computation.

The fundamental science of nanotubes is very exciting, and many of the major academic efforts in nanotechnology center on carbon nanotubes, with important efforts at places like Rice, Harvard, Cornell, Northwestern, Tsukuba, Delft, Tokyo, Stanford, Georgia Tech, Illinois, North Carolina State, and Cal Tech. One of the major challenges of nanotubes has been physical assembly. Because nanotubes tend to stick to one another and do not exhibit the molecular recognition properties more generally associated with organic molecules, manipulating nanotubes using bottom-up techniques unaided by molecular recognition remains a major challenge. Hybrid structures between nanotubes with their attractive physical and electrical properties and soft molecules with their assembly and recognition properties constitute an attractive avenue toward the construction of electronic devices based on nanotube function.

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NANO FOR STUDENTS

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